WINDERMERE BASIN STUDY

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EXECUTIVE SUMMARY

Windermere Basin is a shallow, artificially created basin in Hamilton Harbour which receives surface runoff from Redhill Creek and the treated effluent from the Hamilton sewage treatment plant. During dry weather, loadings are primarily from the Hamilton STP. During wet weather the Basin receives significant additional loadings of suspended solids from the Redhill Creek drainage area.

Past urban and industrial development in the area has resulted in contaminated suspended sediment being contributed to the Basin. As a result contaminated sediments blanket Windermere Basin. Concentrations of contaminants in the sediments exceed by many times the values accepted for open water disposal of sediments. The contaminated sediments appear to occupy primarily the upper seventy centimetres of the sediments but range from a few centimetres to five metres thickness.

Problems are: asthetically unappealing exposed sediments, accumulation of contaminated sediments, and movement of contaminated water from Windermere Basin to Hamilton Harbour . Mitigation requires a reduction of loadings from all sources to the Basin; otherwise, any water and sediment quality improvement strategy will be ineffective. The Hamilton STP is working towards this goal by steadily improving the quality of its final effluent. Erosion control throughout the Redhill Creek drainage basin should be encouraged. Dredging was evaluated as a partial mitigative strategy; however, such a program would not likely show a significant improvement in water quality, and would be very costly.

Further studies are required to define more accurately sediment-water chemistry dynamics to determine if water quality is being impacted across Windermere basin.

TABLE OF CONTENTS

		PAGE NO.
	EXECUTIVE SUMMARY	i
	TABLE OF CONTENTS	ii
	LIST OF FIGURES	iii
	LIST OF TABLES	iii
CHAPTER 1	INTRODUCTION	1
CHAPTER 2	URBAN RUNOFF	4
2.1	Significance	4
2.2	Basin Description	5
2.3	Dry Weather Loadings	6
2.4	Wet Weather Loadings	6
2.5	Average Loadings	8
2.6	Discussion of Loadings	8
CHAPTER 3	SEDIMENTS IN WINDERMERE BASIN	13
3.1	Sediment Characteristics	13
3.2	Volume of Sediments	18
3.3	Biodegradation	24
3.4	Trap Efficiency of the Basin	24
3.5	Contaminant-Sediment Interactions	27
CHAPTER 4	MITIGATIVE STRATEGIES	29
CHAPTER 5	SUMMARY	32
CHAPTER 6	CONCLUSIONS	34

LIST OF FIGURES

		PAGE NO.
1.1	Redhill Creek, Windermere Basin Drainage System	2
1.2	Windermere Basin Shoreline	3
3.1	Windermere Basin Sediment Sampling Stations	14
3.2	Sediment Cross Section	17
3.3	MTC Profile Transect	19
3.4	Sediment Cross Section in Windermere Basin	20
3.5	Cross Profile (90^{o}) to Main Transect	22 - 23

LIST OF TABLES

2.1	1980 Dry Weather Loadings to Windermere Basin	7
2.2	1980 Wet Weather Loadings to Windermere Basin	9
2.3	1980 Average Loadings to Windermere Basin	10
2.4	1980 - 1982 Average Point Source Loadings	12
3.1	Windermere Basin Sediment Quality	16
3.2	Water Quality	26

APPENDIX

A	Sediment Chemistry Data
B	1915 Bathymetric Map of Windermere Basin

1.0 INTRODUCTION

Windermere Basin is a relatively small, 0.4 square kilometre, artificially constructed basin situated at the southeast corner of Hamilton Harbour (Figure 1.1). It was formed as a result of landfilling (reclamation) projects between 1954 and 1972 (Figure 1.2). The drainage area surrounding the basin is urbanized and industrialized. The Basin receives surface runoff from a mixed land use primarily via Redhill Creek and also from the adjacent, surrounding land.

Numerous combined sewer by-passes, storm sewers, and the Hamilton Sewage Treatment Plant discharge directly into Redhill Creek. Until 1981, the Hamilton Water Treatment Plant backwash water was also discharged to Redhill Creek.

Windermere Basin has served as a settling basin reducing the discharge of contaminated solids into Hamilton Harbour. However, because of the accumulation of deposited sediments, large areas of sediments and debris are exposed during low water levels producing an aesthetically displeasing setting.

The purpose of this report is to examine the nature of the material in Windermere Basin, its distribution, source, amount and accumulation rate in order to make decisions on possible solutions dealing with the accumulation of these sediments.

FIGURE: I.I

REDHILL CREEK, WINDERMERE BASIN DRAINAGE SYSTEM

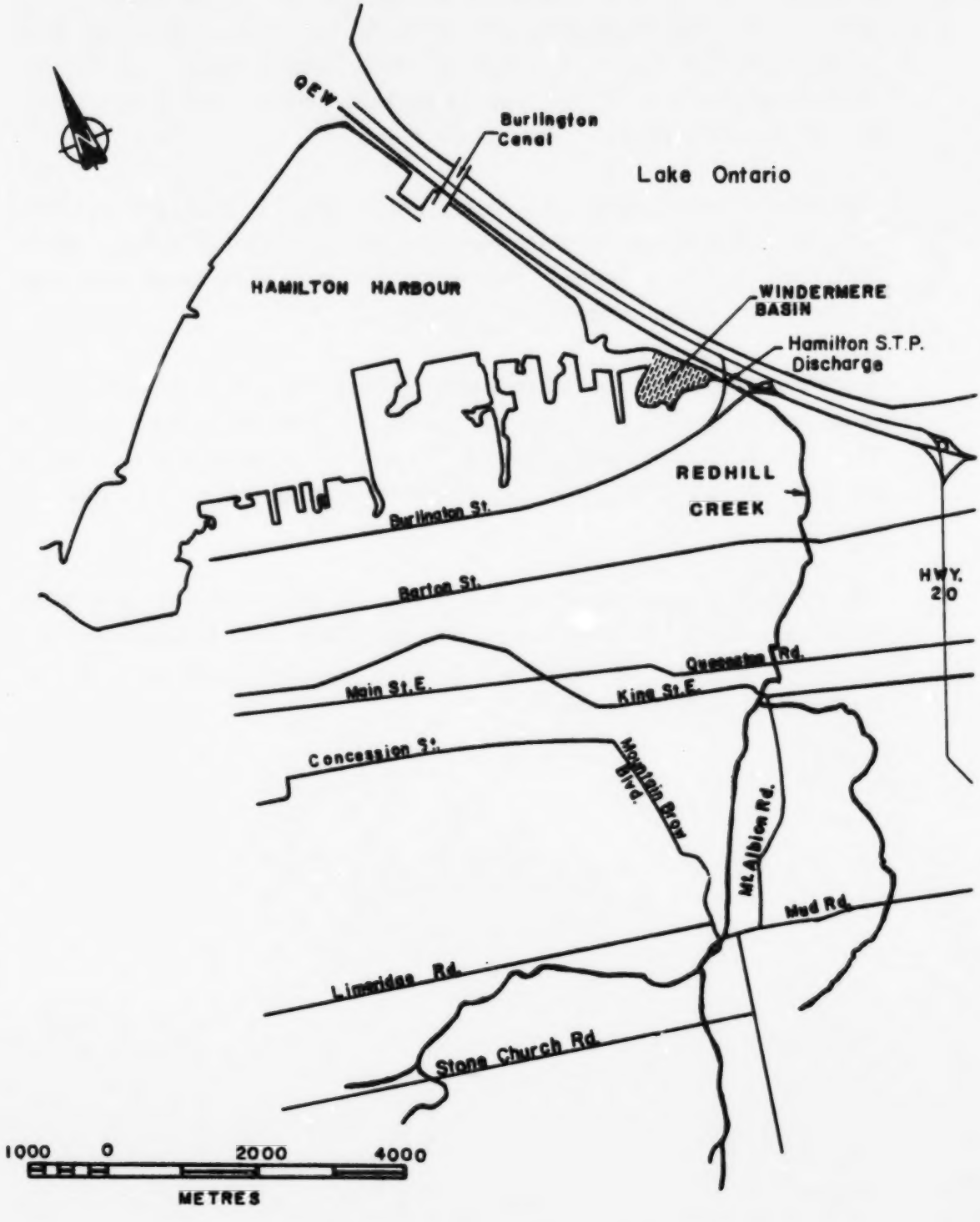
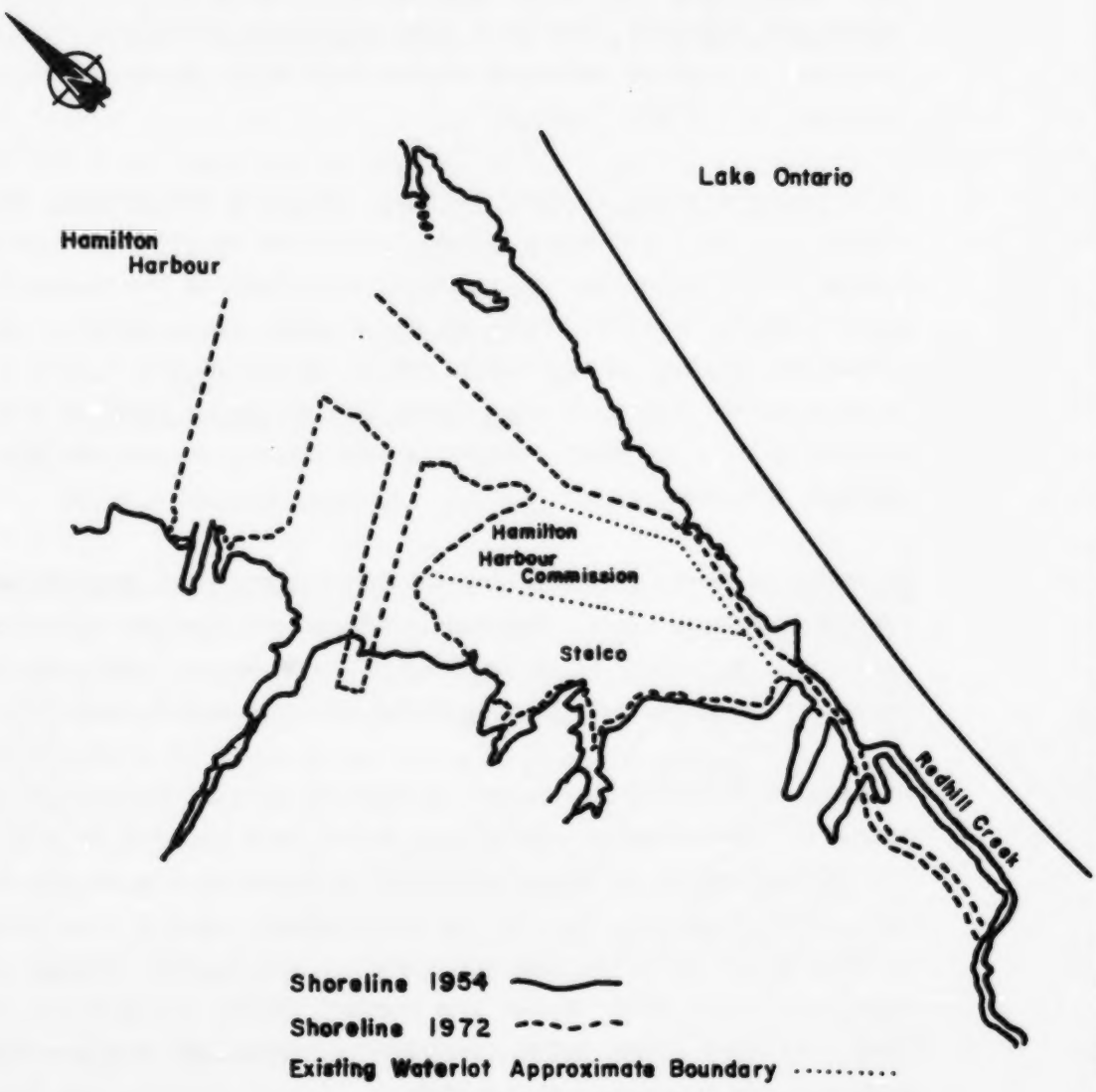


FIGURE:1.2 Windermere Basin Shoreline



2. URBAN RUNOFF

2.1 Significance

In an urban area, point sources (such as sewage treatment plant discharges) pose the greatest single threat to water quality and consequently studies have been emphasized in these areas. A sewage treatment plant, however efficient, can only treat that portion of the total urban pollution load it receives. As point sources are treated and become less threatening to water quality, non-point source water quality impairment becomes relatively more significant (Colston, 1975). Thus pollution loadings to receiving waters from urban storm water runoff can represent significant loadings.

In a separate sewer system, sanitary sewage is conveyed to the sewage treatment plant, and storm water is carried directly to a local water course. This separation reduces hydraulic loads to the sewage treatment plant. Often the first flush of storm water is as polluted as typical untreated sanitary sewage (MOE 1981). Storm sewers receive non-point surface runoff from buildings, lawns and all paved surfaces and contain contamination from dust fallout, animal litter, automobile gas and oil leakage, fertilizer, etc.

In combined sewer systems, dry weather sewage flows are carried to the sewage treatment plant. However, during wet weather when the sewer capacity is exceeded by large flows of storm water, combined untreated sewage is by-passed via sewer outflows to a convenient receiver.

In general terms, urban runoff introduces oxygen demanding materials, nutrients, heavy metals, solids and undesirable bacteria to local waters. The concentrations of oxygen demanding materials are usually less than the concentrations in typical untreated sewage, whereas the concentrations of solids and heavy metals are usually greater in urban runoff (Colston, 1975; Wilber and Hunter, 1975). In addition, the high flows resulting from urban drainage systems can produce increased erosion in the receiving water system.

2.2 Basin Description

The City of Hamilton is divided physiographically by the escarpment into two sections:

- The lower older section of the City built around the Harbour, and
- The upper newer section of the City built on the escarpment.

The older section is serviced almost exclusively by a combined sewer system. The newer section is serviced primarily by separate storm and sanitary sewer systems.

The total sewer serviced area in Hamilton is 120.6 sq. km (James, 1982). Separated storm flows, urban drains and sanitary sewage by-passes reach Hamilton Harbour through three drainage systems:

1. Redhill Creek - (66.4 sq. km)
2. Chedoke Creek - (26.8 sq. km)
3. Central Business District - (27.4 sq. km)

The most significant is Redhill Creek, which drains into Windermere Basin. It is the least urbanized of the three drainage basins. Agricultural lands compose 60% of the basin and single family dwellings occupy 31% of the drainage area. The remaining 9% is occupied by industrial, commercial, institutional and multi-family dwellings, structures and holdings.

Twenty percent of the Redhill Creek drainage basin is serviced by combined sewers, which have overflows located at Greenhill Avenue, Lawrence Road, Queenston Road and Barton Street.

The Hamilton Water Treatment Plant, located on Woodward Avenue, pumps water from Lake Ontario, and treats it prior to distribution. In the past the effluent from the backwashing of the filters was flushed directly to Redhill Creek. Since January 1981, this backwash water has been

directed to the sewage treatment plant and is no longer a point source loading to the basin.

2.3 Dry Weather Loadings

During dry weather, contaminant loadings to Windermere Basin consist principally of inputs from the Hamilton Sewage Treatment Plant and Redhill Creek.

With an average base flow of approximately 0.14 cubic metres per second (CMS) (12,000 m^3/day), Redhill Creek discharges about 68 kg/d of BOD_5, 154 kg/d of suspended solids, 104 kg/d of ammonium nitrogen and 9.5 kg/d of total phosphorous (Table 2.1) during low flow periods.

The loadings from the alum sludge filter backwash from the Hamilton Water Treatment Plant which were discharged to Redhill Creek until 1982 are estimated to have been 56 kg/d BOD_5, 2,640 kg/d suspended solids, 19 kg/d nitrogen, and 7 kg/d total phosphorous.

The 1980 dry weather loadings from the Hamilton sewage treatment plant to Redhill Creek and Windermere Basin are shown in Table 2.1. Having an average dry weather flow of approximately 53 million gallons per day or 241,000 m^3/day, the sewage treatment plant discharged 5,760 kg/d of BOD_5, 8,160 kg/d of suspended solids, 8,640 kg/d of ammonium nitrogen and 432 kg/d of total phosphorous.

2.4 Wet Weather Loadings

The storm water loadings to Windermere Basin from the Redhill Creek system include combined sewer overflows, separate storm water runoff and scouring induced by high flows in sewers and Redhill Creek. Erosional problems caused by high storm flows are readily observed by visual inspection of the Redhill Creek banks. Wet weather loadings occurred on 20% of the days in 1980; this does not include snow melt.

As a result of the previously unquantified nature of these loadings and the realization that such loading data would be necessary to the development of an overall water quality management plan for Hamilton

TABLE 2.1

1980 DRY WEATHER LOADINGS TO WINDERMERE BASIN

All Loadings in kg/d

Loadings - Urban Non-Point	Flow (m^3/d)	Biochemical Oxygen Demand	Suspended Solids	Ammonium Nitrogen	Total Phosphorous
Redhill Cr.	12,000	68	154	104	9.5
Parkdale c/s	0	0	0	0	0
Woodward c/s	0	0	0	0	0
Total Urban Non-Point	12,000	68	154	104	9.5
Loadings - Urban Point					
Hamilton STP*	241,000	5,760	8,160	8,640	432
Hamilton WTP**		56	2,640	19	7
Total Urban Point	241,000	5,816	10,800	8,659	439
Total Estimated Loadings - All Sources	253,000	5,884	10,954	8,763	449.

* Treatment modification @ STP have reduced these loadings since 1980.

** WTP Filter Backwash now directed to STP

c/s - Combined sewer overflow

Harbour, the Ministry of the Environment awarded a contract in the fall of 1979 to Computational Hydraulics Incorporated to estimate the magnitude of storm generated loadings to Hamilton Harbour. While final loading calculations should be complete in the spring of 1983, some preliminary results are available.

Total wet weather loadings from the drainage basin are presented in Table 2.2 and were derived from "average" storm data provided by W. James and M. Robinson, (1981). Loadings were based primarily on summer sampling periods extrapolated over the entire year.

Loadings of suspended solids are significantly increased during wet weather events. Urban non-point sources contributed the greatest fraction of suspended solids, accounting for 144,000 kg/d while the STP contributed 13,770 kg/d.

The Hamilton STP contributed three times more BOD_5 (7830 kg/d), fifteen times more ammonium nitrogen (9540 kg/d) and twice as much total phosphorous (497 kg/d), as urban non-point sources.

2.5 Average Loadings

Average loadings illustrate the relative influence of wet and dry conditions. Table 2.3 gives the results for average conditions. These results show that the Hamilton STP accounted for 245,000 m^3/d of the total 286,000 m^3/d flow entering Windermere Basin. However, on average, 46,080 kg/d of suspended solids entered Windermere Basin (James, 1980) from total non-point loading compared with 9,065 kg/d suspended solids from the STP in 1980. The Hamilton STP treatment plant accounted for 443 kg/d total phosphorous and 6125 kg/d BOD_5. Urban non-point sources yielded only 73 kg/d total phosphorous and 740 kg/d BOD_5.

2.6 Discussion of Loadings

Suspended solids loadings to Windermere Basin from urban non-point sources particularly Redhill Creek, account for over 80% of the 57,785 kg/d suspended solids. These suspended solids are transported almost

TABLE 2.2

1980 WET WEATHER LOADINGS TO WINDERMERE BASIN

All Loadings in kg/day

Loadings - Urban Non-Point	Flow (m^3/d)	Biochemical Oxygen Demand	Suspended Solids	Ammonium Nitrogen	Total Phosphorous
Redhill Cr.	80,000	2,040	122,000	576	189
Parkdale c/s	2,000	258	15,300	78.5	26.3
Woodward c/s	3,000	125	6,580	34.0	10.0
Total Urban Non-Point	85,000	2,423	143,880	689	225
Loadings - Urban Point					
Hamilton STP*	271,000	7,830	13,770	9,540	497
Hamilton WTP**		56	2,640	19	7
Total Urban Point	271,000	7,886	16,410	9,559	504
Total Estimated Loadings - All Sources	356,000	10,309	160,290	10,248	729

* Treatment modification @ STP have reduced these loadings since 1980.
** WTP Filter Backwash now directed to STP.
c/s - Combined Sewer overflow

TABLE 2.3

1980 AVERAGE LOADINGS TO WINDERMERE BASIN

All Loadings in kg/day

Loadings - Urban Non-Point	Flow (M^3/d)	Biochemical Oxygen Demand	Suspended Solids	Ammonium Nitrogen	Total Phosphorous
Redhill Cr.	37,000	617	39,000	186	60.8
Parkdale c/s	3,000	83	4,940	25.4	8.6
Woodward c/s	1,000	40	2,140	10.9	3.6
Total Urban Non-Point	41,000	740	46,080	222	73.0
Loadings - Urban Point					
Hamilton STP*	245,000	6,125	9,065	8,820	443
Hamilton WTP**		56	2,640	19	7
Total Urban Point	245,000	6,181	11,705	8,839	450
Total Estimated Loadings - All Sources	286,000	6,921	57,785	9,061	523

* Treatment Modification @ STP have reduced these loadings since 1980.
** WTP Filter Backwash now directed to STP
c/s - Combined sewer overflow

exclusively during wet weather flow. However, during dry weather, total urban non-point sources account for 1 - 2% of the total loadings to the basin. The Hamilton STP loadings for all parameters increase much less during wet weather flows than loadings from urban non-point sources.

The Hamilton STP produced the most significant loadings of biological oxygen demand, ammonium nitrogen and total phosphorous in 1980.

The Hamilton sewage treatment plant is continuing its efforts to reduce loadings in its effluent. Table 2.4 gives loadings for the first eleven months of 1982. The total daily flow is higher than the flow increasing from 245,000 m^3/d to 286,000 m^3/d. Biological oxygen demand (BOD) has been reduced from 6181 kg/d to 3160 kg/d, suspended solids (SS) has reduced from 11,705 kg/d to 4900 kg/d, and total phosphorous has reduced from 450 kg/d to 316 kg/d. Ammonium nitrate has increased slightly from 8830 kg/d to 9660 kg/d.

The STP is producing an effluent consistent with that expected from a secondary treatment system. Further significant improvement would require tertiary treatment or process modification. It is expected that loadings from the STP will remain the most significant loadings of BOD, suspended solids, ammonium nitrogen and total phosphorous. However, suspended solids loadings from urban non-point sources yield the bulk of sediment forming suspended solids.

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TABLE 2.4

1980 - 1982 AVERAGE POINT SOURCE LOADINGS TO WINDERMERE BASIN

All Loadings in kg/d

		Flow (m^3/d)	Biochemical Oxygen Demand	Suspended Solids	Ammonium Nitrogen	Total Phosphorous
1980 -	Hamilton STP	245,000	6,125	9,065	8,820	443
	Hamilton WTP		56	2,640	19	7
	Total	245,000	6,181	11,705	8,839	450
1982 * -	Total	287,000	3,160	4,900	9,660	316

**now includes Water Treatment Plant Filter backwash - data extrapolated from 11 months data

3. SEDIMENTS IN WINDERMERE BASIN

3.1 Sediment Characteristics

The bulk of the sediments deposited in Windermere Basin are fine grained inorganics and organic particles primarly from the Redhill Creek drainage basin.

The mean specific density of 10 samples of surface deposits (obtained by 15 cm Eckman dredge) ranged from 1.17×10^3 to 1.65×10^3 kg/m^3 with a mean of 1.27×10^3 kg/m^3. This compares to the density of water which is approximately 1.0×10^3 kg/m^3 and the specific density of beach sand which is approximately 2.3×10^3 kg/m^3. The mean dry bulk density of these samples is 3.7×10^2 kg/m^3 similar to soils with a high organic content.

The percent solids in the surface deposits vary from 11% near the Basin outlet to 63% at the mouth of Redhill Creek (Appendix A). The variation is due to denser material settling near the mouth of the creek while less dense material is dispersed throughout the Basin.

Over many, many years sediment deposition has formed a complex delta at the mouth of Redhill Creek. Accumulated sediments within an area of 200,000 sq. metres (ie., half of the Basin) extend above the normal low water level (Figure 3.1). Two indistinct channels have formed around the perimeter of the Basin. The channel on the northeast side of the Basin carries most of the flow from Redhill Creek; sediments deposited in this area have a higher percent solids content (ie., approximately 50 to 60% solids). A channel on the south side of the basin mainly carries flow from the Sewage Treatment Plant (STP). Sediments in this area have a much lower percent solids (ie., approximately 15 to 30%).

The sediments between the two main channels are submerged during the winter, spring and early summer. The depth of water in the Basin is dependent on the hydrology of Lake Ontario and/or Hamilton Harbour rather than on the hydrology of Redhill Creek.

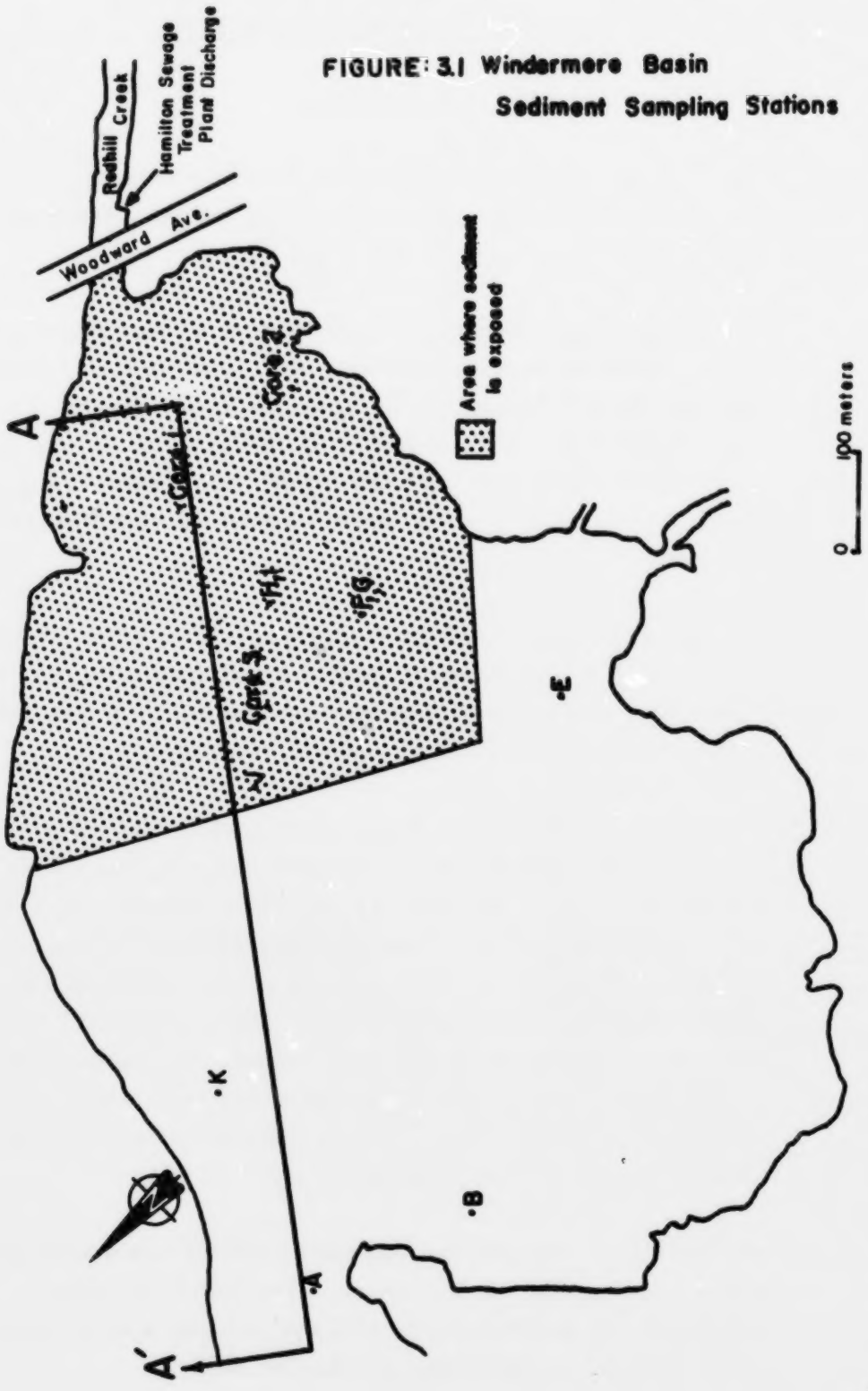


FIGURE: 3.1 Windermere Basin
Sediment Sampling Stations

During periods of high water, flow will disperse over the delta and deposition will occur laterally across the entire Basin. During low water levels, distinct plumes persist approximately halfway through the Basin.

The sediment deposits are composed of a layer of soft black sediments overlying brown silty sand. These are covered by a layer of sewage floc (loosely packed organic particles) in the vicinity of the mouth of Redhill Creek and the STP outfall.

Water depths reach a maximum of 1.5 m near the outlet of Windermere Basin to Hamilton Harbour.

Vertical coring at 11 locations (Appendix A) indicated a composition of 15 to 20% solids (except near the mouth of Redhill Creek) at the surface of the sediments more than doubling to 40 to 50% at depths of 70 centimetres, due to settling and compaction.

The horizontal distribution of specific sediment quality is shown in Appendix A. Table 3.1 shows mean and maximum levels of contaminants. Table 3.1 also lists guidelines for acceptable open lake disposal of dredged material, along with EPA sediment classifications for comparison purposes. Contaminant concentrations greatly exceed MOE guidelines for open water disposal. Ranges of sediment contamination have been established for the Great Lakes, and can be divided into non-polluted, moderately polluted, and heavily polluted sediments (Fitchko and Hutchinson, 1975; and EPA, 1977 Guidelines). The surface sediments collected in 1976 in Windermere Basin were found to be 10 to 30 times higher than levels considered to be heavily polluted. Excessive concentrations occurred in the area where the less dense floc is at or near the surface of the water (Figure 3.2), near the outlet of Redhill Creek and the Sewage Treatment Plant. Across Windermere Basin concentrations of heavy metals in the sediments decreased from maximum values near the sewage treatment plant outfall to about half those values near the outlet of the Basin. A report (MOE, 1976) on polychlorinated biphenyls (PCBs) states that a level of 10 mg/kg was found in one sample near the sewage treatment plant outfall. Resampling in 1980 indicated a level of 1 mg/kg near the sewage treatment plant outfall. It is possible that the sample was not taken from the exact same location and therefore the actual change in PCB levels may not be reflected by these results.

TABLE 3.1

WINDERMERE BASIN SEDIMENT QUALITY

Paramter	MOE Guidelines	EPA 1977 Guidelines[2]			Windermere Basin Sediment[3]	
		Non Polluted	Moderately Polluted	Heavily Polluted	Mean	Max.
Loss on Ignition	6%	< 5%	5% - 8%	> 8%	25%	43%
Total Kjeldahl Nitrogen	.2%	< .1%	.1% - .2%	> .2%	1.3%	2.9%
Total Phosphorus	.1%	< .042%	.042% - .065%	> .065%	1.3%	2.4%
PCB	50. ug/kg	*	*	*		10,000 ug/kg
Mercury	.3 mg/kg	< 1.0 mg/kg	*	> 1.0 mg/kg	1.6 mg/kg	3.4 mg/kg
Lead	50. mg/kg	< 40. mg/kg	40 - 60 mg/kg	> 60. mg/kg	700.0 mg/kg	1,100 mg/kg
Zinc	100. mg/kg	< 90. mg/kg	90 - 200 mg/kg	> 200. mg/kg	3,400. mg/kg	5,200 mg/kg
Chromium	25.0 mg/kg	< 25. mg/kg	25 - 75 mg/kg	> 75. mg/kg	1,070. mg/kg	1,800 mg/kg
Copper	25.0 mg/kg	< 25. mg/kg	25 - 50 mg/kg	> 50. mg/kg	500. mg/kg	800 mg/kg
Cadmium	1.0 mg/kg	*	*	> 6. mg/kg	12. mg/kg	18 mg/kg
Iron	1.0 %	< 1.7 %	1.7% - 2.5%	> 2.5%	4.2%	5.5%

* Not Established

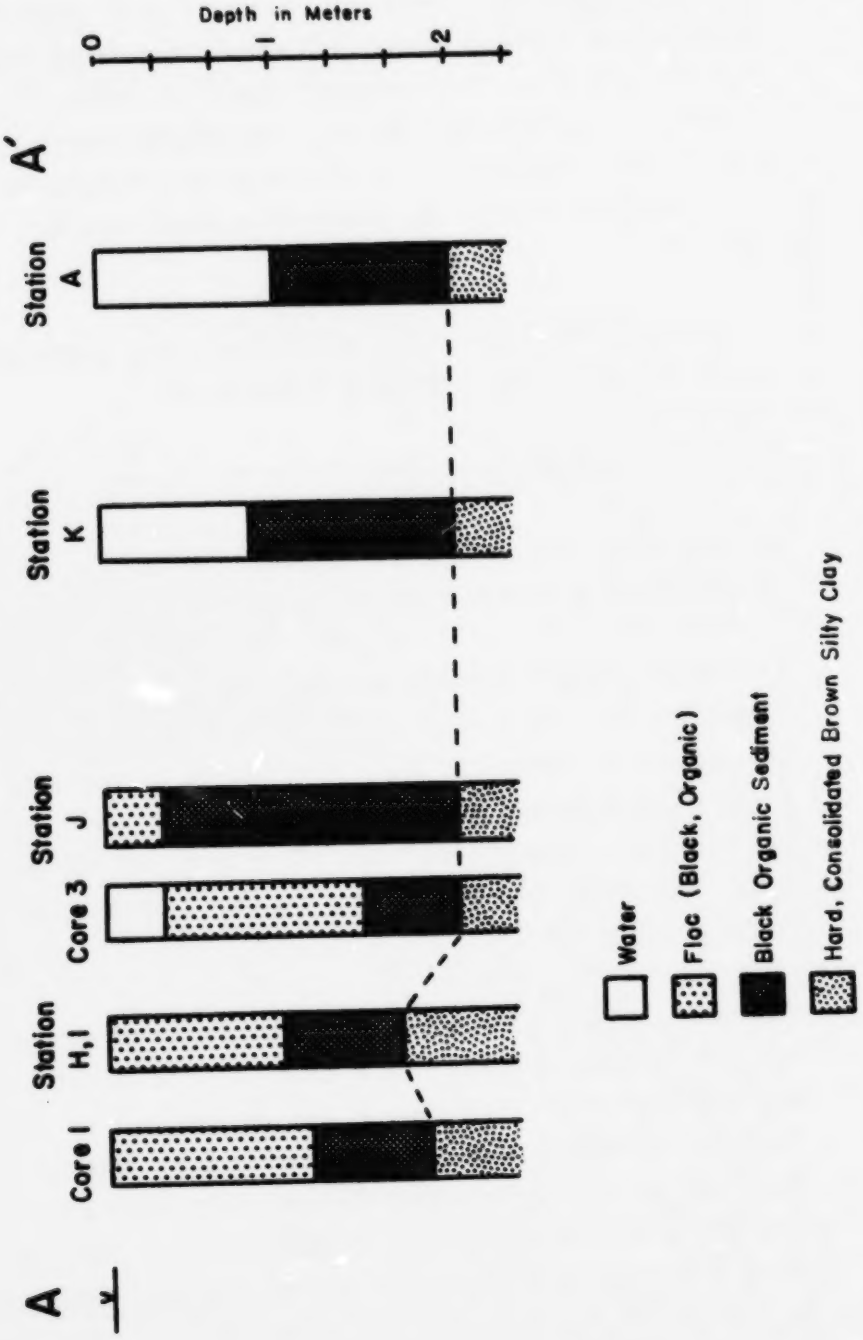
1. Guidelines suggested as indicative of contaminated sediments used in MOE evaluation of dredging project for consideration for open water disposal.

2. EPA 1977 Guidelines from IJC Upper Lakes Report. Appendix C: Ranges used to classify sediment from Great Lakes Harbours.

3. Values used are from analysis of 10 surface sediments.

FIGURE: 3.2 : Sediment Cross-Section,
(Refer to figure 3.1 for station locations)

Section A-A′
Low Water Level



The maximum value of total phosphorous (24 mg/g or approximately 2.4% of the sediment by weight) occurred at the surface of the sediment and decreased markedly to less than 1 mg/g at 75 centimetres depth. Loss on ignition (indicating organic content) decreases from a maximum value of 37% at the surface to an average value of approximately 10% at about 50 centimetres depth. The pattern is interesting in that several parameters including cadmium, chromium, copper, lead, mercury, zinc and total phosphorous followed similar patterns, decreasing from a maximum value at the surface to "background" levels at about 70 centimeters depth. However, Total Kjeldahl Nitrogen decreased from a maximum value of 21 mg/g to an average value of approximately 4 mg/g but increased again at 70 centimetres depth. No explanation could be found for this anomoly to date.

In summary the upper 70 cm of the sediments examined were found to be the most contaminated sediment in the Basin.

3.2 Volume of Sediment

In assessing the volume of sediment deposited in the basin various historic maps and notes were reviewed.

The most valuable information is provided by a map produced in 1915 (Appendix B). This map clearly shows that the present basin contours are similar to those of 1915. The depth of the area occupied by the present basin ranged in depth from 0.3 m (1 ft) to 1.8 m (6 ft) except for two trenches. One channel was 540 m long and 100 m wide at its widest point, the other was 260 m long by about 30 m wide. Both reached a depth of 4.9 m (16 ft).

The most current information on the thickness of sediment deposits in the Basin is found in a geotechnical study by the Ministry of Transportation and Communication. This work was carried out as part of a feasibility study for foundations of the proposed Q.E.W. arterial roadway along the Beach Strip. The measurements were taken along a transect (Figure 3.3) adjacent to the northeast side of the Basin. A cross-section constructed along the transect (Figure 3.4) shows a general depth of approximately 3 to 4 metres of black organic silt underlain by brown silt and sand. The

FIGURE: 3.3

MINISTRY of TRANSPORTATION and COMMUNICATION
PROFILE TRANSECT

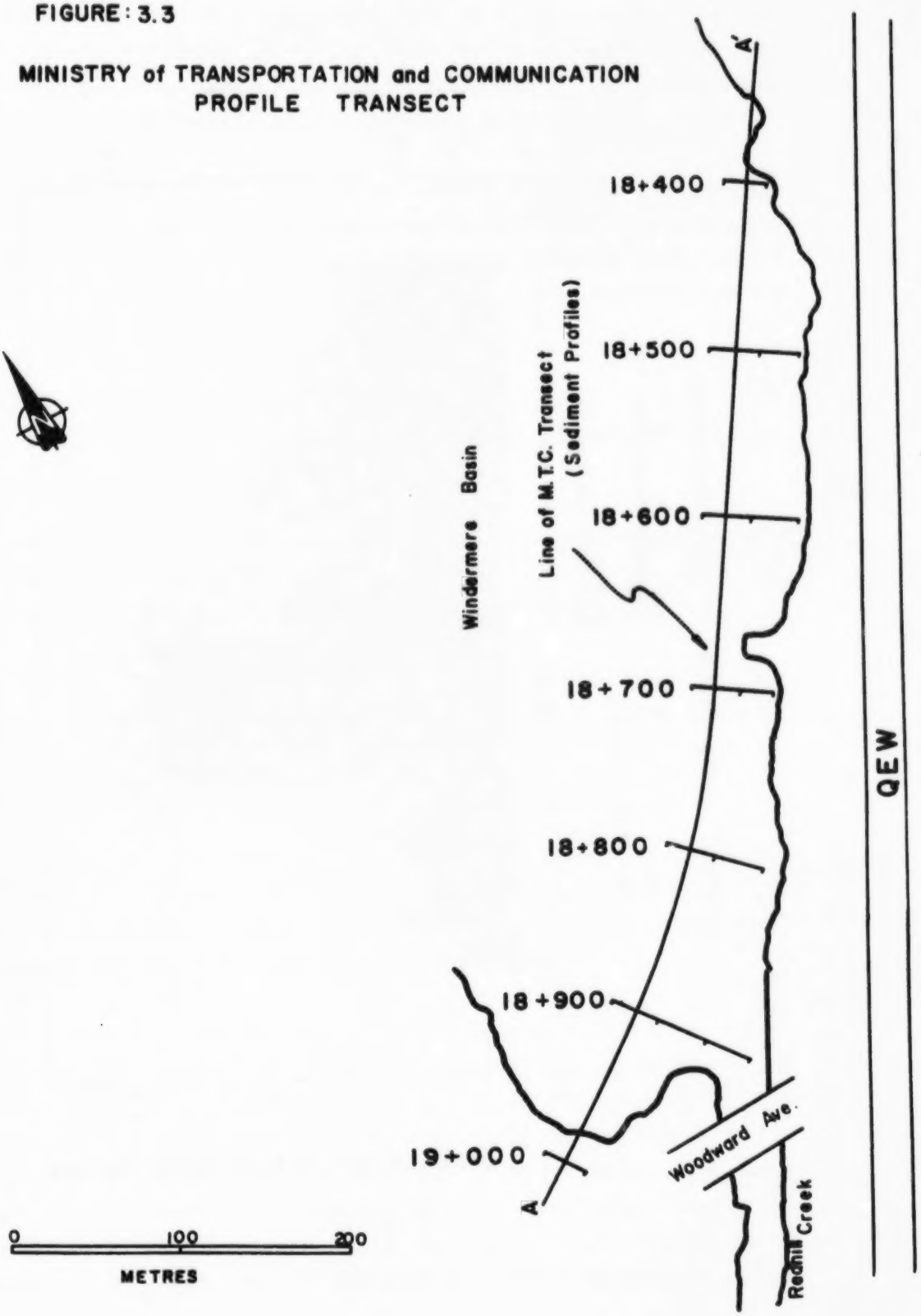
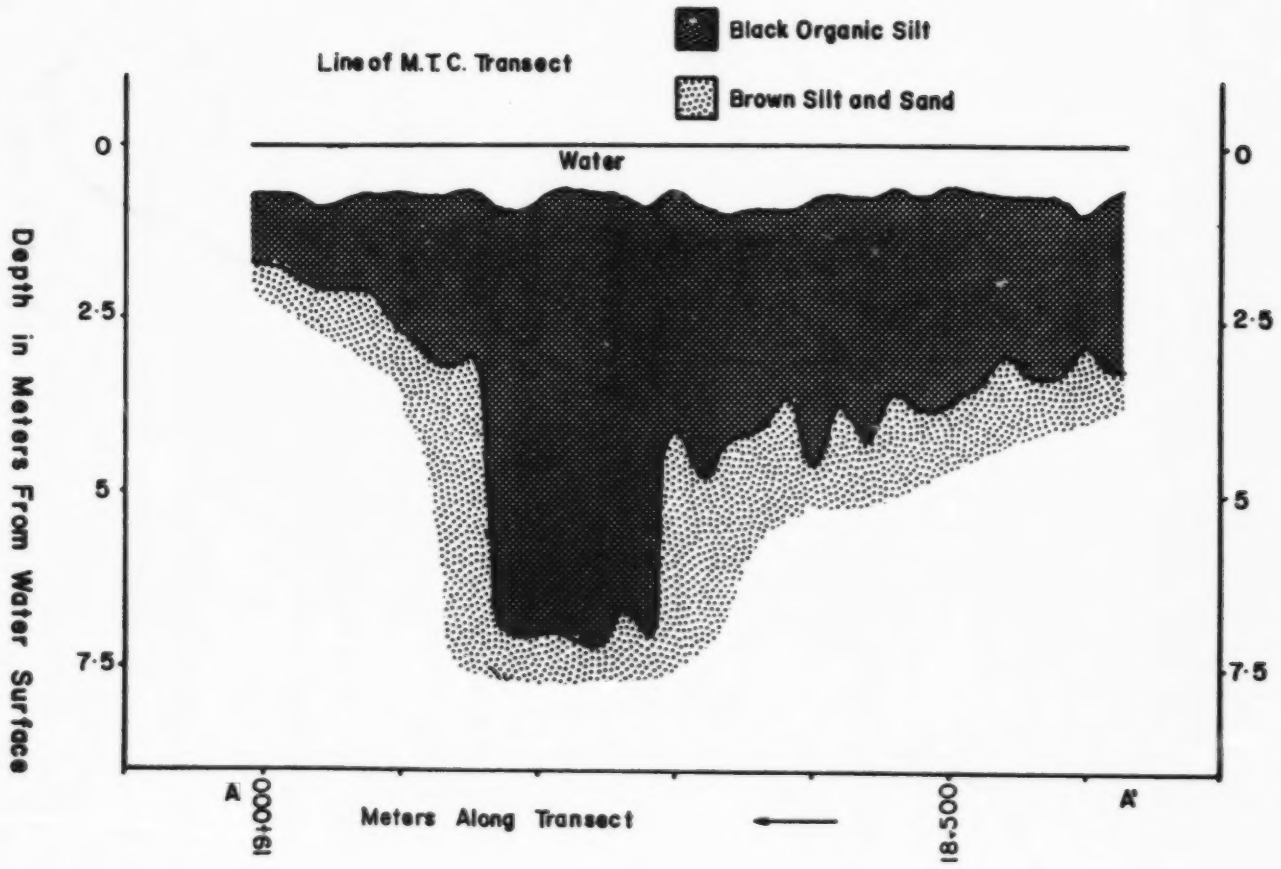


FIGURE: 3.4

Sediment Cross Section in Windermere Basin



contact between the two sedimentary units is undulating except for the area between station 18 + 700 metres and 18 + 850 metres along the transect where a pronounced buried trench exists exhibiting a depth of up to 7 metres. This trench is located off the mouth of Redhill Creek and might represent a submerged channel formed in earlier geologic time.

The existence of this trench as a continuation of Redhill Creek is further indicated by the cross-sections constructed perpendicular to the transect (Figure 3.5). Profile 18 + 899 (Figure 3.5) shows a defined creek bed off the mouth of the creek. This trench (now filled) is undoubtedly the one shown in the 1915 map.

While MTC borehole information indicates a thickness of 3.5 m of black organic sediments, historic maps show that much of this sediment was deposited prior to 1915.

The boundary between the recent potentially contaminated sediments and underlying older sediments cannot be determined visually (they are similar in colour and consistency to underlying sediments).

These contaminated sediments may vary in thickness from just a few centimetres to a metre or more in thickness. The small trenches shown in the historic map and located in MTC's exploratory work contain up to 5 m of potentially contaminated sediment.

The volume of the Basin prior to the deposition of all organic sediments, is estimated to be about 1.4 million cu. metres. The organic sediments occupy approximately 1 million cu. metres reducing the present Basin volume to 400,000 cu. metres during high water levels.

Since the mean dry bulk density of the sediments are 3.4×10^2 kg/m^3 then organic rich sediment deposits weigh 3.4×10^8 kg. It would require only 1.4×10^8 kg of additional sediments to displace the remaining 400,000 cu. metre Basin. At the estimated suspended solids loading rate of 5.78×10^4 kg/d or 2.1×10^7 kg/yr (Table 2.3), if all incoming solids were trapped by the basin, the existing partially filled basin would fill completely in 7 years. However, over the past six years the volume of sediments in the Basin has not appeared to increase significantly. The

FIGURE 3.5 Cross Profiles (90°) to Main Transect

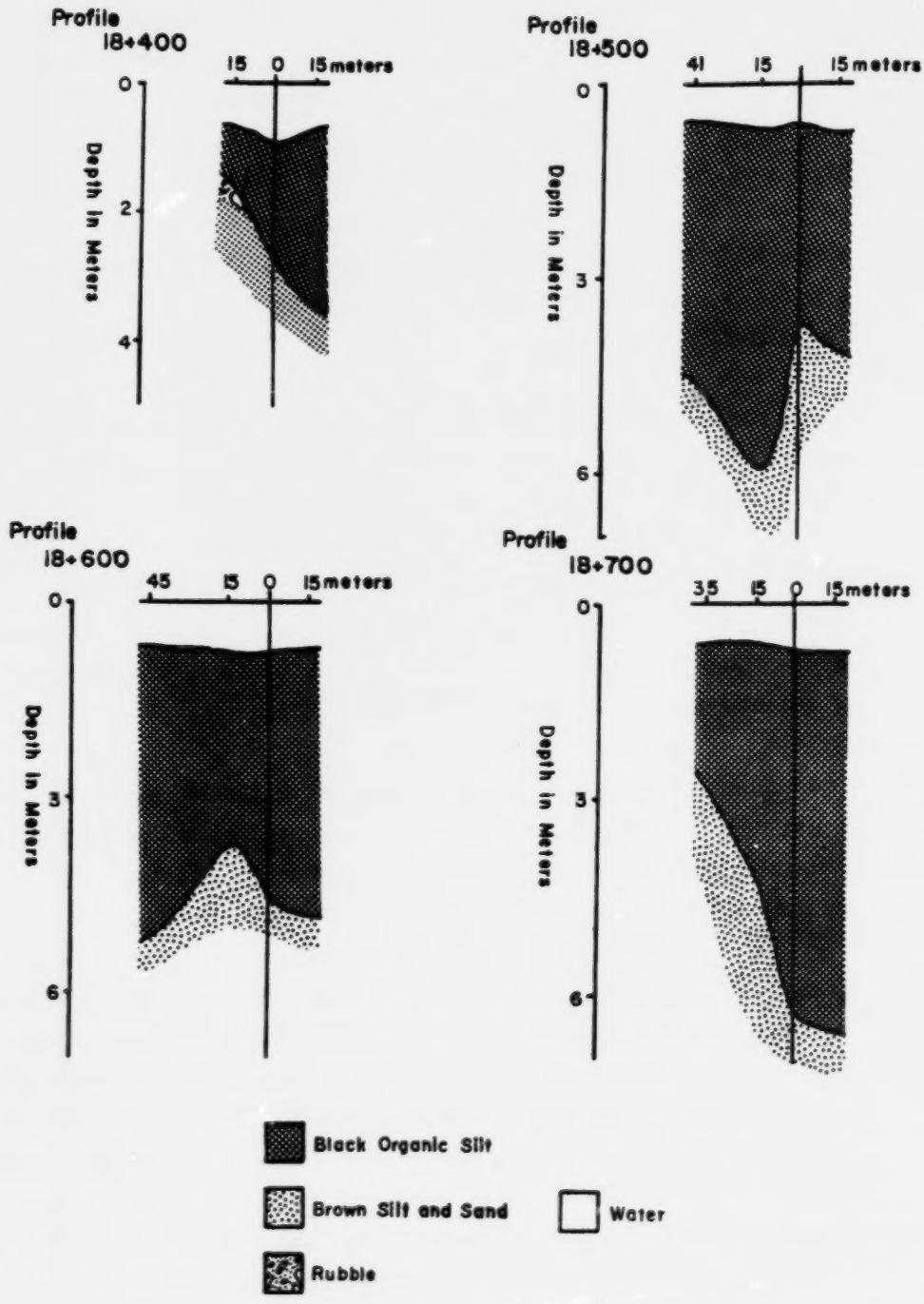
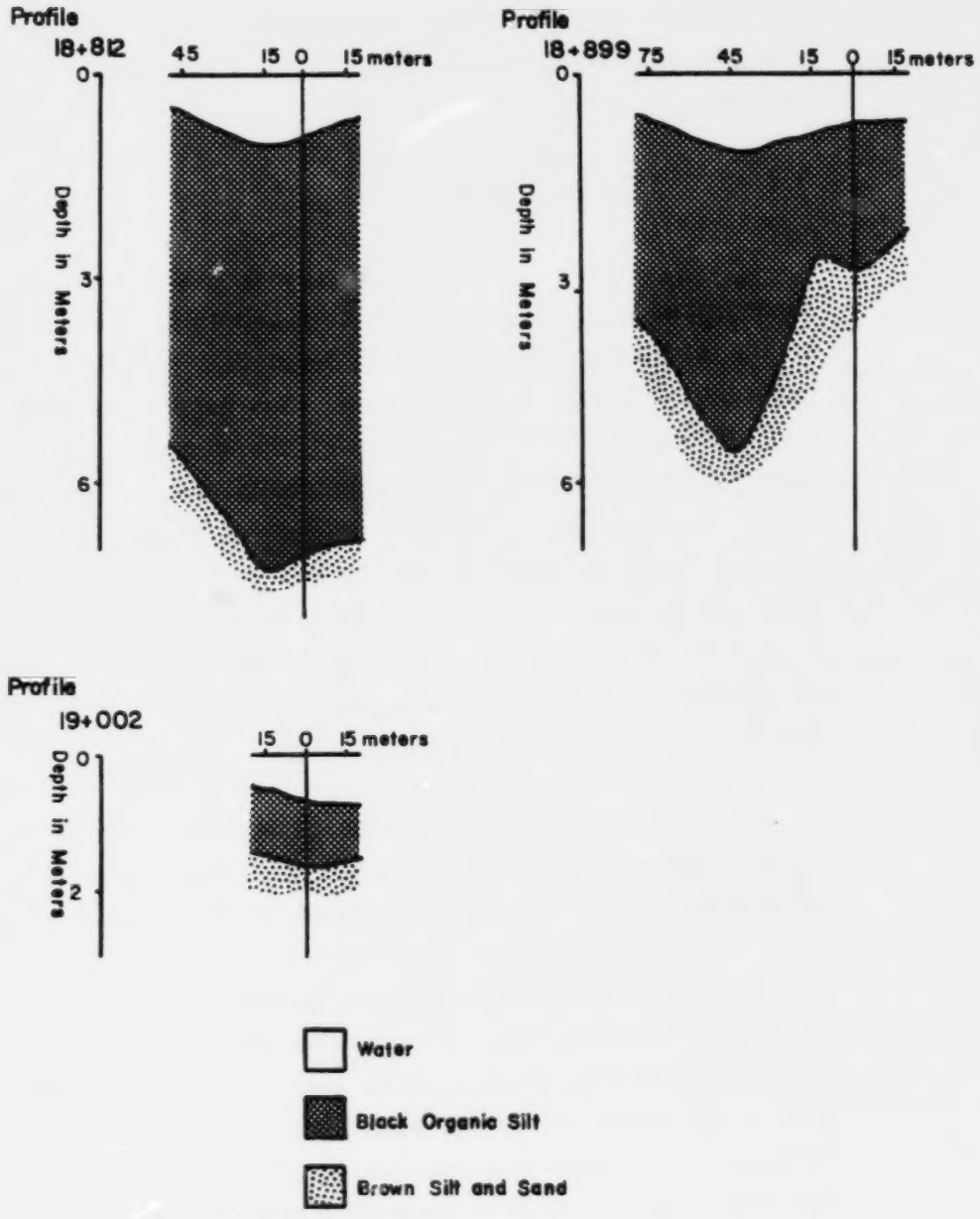


FIGURE 3.5 Cross Profiles (90°) to Main Transect



reasons for this discrepancy is that the Basin is not a perfect settling facility, and/or sediments are degrading and compacting.

These estimates of loading rates and sediment volumes are based on current Basin characteristics and loading rates. It should be kept in mind that urban non-point loading rates and characteristics change seasonally, and are affected by land use, industrial operation, weather, and urban development, particularly during construction. Seasonal changes in loadings will cause some variation in the density of the sediments.

3.3 Biodegradation

Biodegradation of organic materials accounts for some reduction in volume of the sediment. Water in the Basin has low dissolved oxygen levels generally less than 50% saturation. Gas generation and bubbling can be seen throughout the Basin during the summer months resulting from bacterial decomposition of organic deposits.

3.4 Trap Efficiency of the Basin

The trap efficiency of a body of water depends on the sediment characteristics and the rate of flow through that body of water (Chow, 1964).

As the streamflow enters the wide basin from Redhill Creek, the cross-sectional area of flow greatly increases thereby decreasing flow velocities and increasing the settling efficiency or trap efficiency.

The settling velocity depends on suspended particle size and shape, and the viscosity and density of the water. Coarse inorganics will settle out first. The density of the organics is only slightly greater than that of water and therefore the organics have low settling velocities. Fine inorganics also have low settling velocities. Particles with low settling velocities will stay in suspension for a much longer period of time.

The rate of flow through the Basin determines the detention time (or flushing rate). The detention time for the Basin is 1 to 2 days depending on water volume and the incoming flow. The volume of the basin is dependent on water levels that typically fluctuate approximately 30 cm annually.

Chow (1964) presents a graphical relationship between the capacity - inflow ratio and % of incoming sediment trapped. Capacity - inflow ratio is the ratio between basin volume and the volume of annual inflow. Using this procedure the trap efficiency for the empty Basin with a mean depth of 3.5 m was estimated at 40 to 65% with a median of 55%.

Efficiency for the Basin in its present condition is 0 to 20%. This corresponds with the visual observations of the sediments over the past six years that indicate that the sediment surface has not noticeably changed since 1976 when the Ministry of the Environment's studies were started on the basin.

Low trap efficiency is also suggested by observations made by The Regional Municipality of Hamilton-Wentworth which in 1976, stated:

> "... twenty years ago (re: 1976) the average depth of the basin was about 2 feet (60 cm) below the chart datum level of 243 feet (74 m). Last year (1975) the average datum was 244 feet (74.3 m) and yet the unsightly mud flats were exposed. This would indicate that the bottom has raised about 3 feet (1 m) in that period of time".

These points indicate the Basin has been slowly filling for many years trapping only a small portion of the incoming solids.

Surface water samples were taken of the inlet and outlet of Windermere Basin (Table 3.2) during the summer months of 1977 and 1980 to establish the trap efficiency of the Basin. Samples were collected during both wet weather and dry weather flows. Due to dynamic relationships in the Basin it was not possible to dissociate the effects of sediment entrapment vs biodegradation. However, some apparent trends were observed. The most consistant changes in water quality between the mouth of Redhill Creek and the outlet from Windermere Basin are shown by reductions in

TABLE 3.2

WATER QUALITY

ALL Concentrations in mg/l

	STP	Redhill Creek	Outlet from Winderemere Basin
Flow m^3/day	245,000*	37,000**	
Zinc	< .03	< .15	< .03
Copper	< .03	< .02	< .01
Lead	< .03	< .03	< .03
Cadmium	< .005	< .005	< .005
Chromium	< .02	< .05	< .02
Manganese	.30	.11	.10
Aluminium	.24	.23	.28
Iron	.46	.02	.60
Nickel	.02	.04	.04
BOD_5	25*	4.0	4.0
Suspended Solids	37*	45	12
Turbidity	8.6	7.8	4.0
Total Kjeldahl Nitrogen	41	12	21
Total Phosphorous	1.81*	.45	.54

* average for 1980 STP Operating Data

** Water survey of Canada Average daily flow for 1980

manganese, BOD, suspended solids, turbidity, total kjeldahl nitrogen and total phosphorous. Zinc, copper, lead, cadmium and chromium did not exhibit a clear trend and were generally below analytical detection limits.

In summary, a low trap efficiency in the present Basin is suggested by theoretical calculations, visual observations and inferences from chemical analytical data.

3.5 Contaminant - Sediment Interactions

Prime concerns for Windermere Basin are the fate of contaminants entering the Basin and the reduction (or increase) of contaminants moving out of the Basin.

There are many mechanisms for the capture and release of heavy metals to and from the water column in the Basin. Heavy metals may be classified into at least two different catagories:

a) in solution as free or complexed ions,

b) in particles, sorbed onto particles or incorporated into living biomass or as inorganic precipitates (ie., hydroxides, carbonates, sulphides, sulphates).

The fate of heavy metals relates directly to their states and the existing environmental conditions. Many metals in wastewater are found as particles forming very insoluble sulphides (Zinc, Silver, Mercury, Copper, Cadmium, Lead) and oxides (Chromium, Iron) forms, while some (Nickel, Colbalt, Manganese) are relatively soluble (Huang et al, 1977).

Heavy metals in solution may be removed by adsorption and precipitation mechanisms. Heavy metals in suspended particulates may be transformed by dissolution and/or precipitation. Sediments can become enriched with heavy metal precipitates and will be both a source and a sink of contaminants.

Chen et al (1975) reported that the suspended particles from urbanized drainage channels were found to contain heavy metals in the same

magnitude as the suspended particles from wastewater effluents. However, this has not been demonstrated in Windermere Basin.

Dissolution of relatively insoluble substances from sediments through biological activities contributes to the chemical composition of water. Gas generation and bubbling in Windermere Basin is constant in the summer months, indicating the digestion of sediments by micro-organisms. Gould and Genetelli (1975) reported that a high correlation exists between heavy metal content and volatile solids. Decomposition of the volatile solids can potentially release the associated contaminants.

There is therefore concern that the sediments could release contaminants to the water column in Windermere Basin. The data in Table 3.2 indicate that reductions in most contaminants occur across the Basin but more detailed studies would need to be carried out to specifically define contaminant-sediment interactions.

4. MITIGATIVE STRATEGIES

The most obvious problem with Windermere Basin is aesthetic, caused by the deposition of sediment and debris carried by Redhill Creek. An excessive build-up of aesthetically displeasing contaminated materials has occurred in the Basin, and as the build-up continues, larger loadings are discharged to the rest of Hamilton Harbour as more material passes through the Basin. Mitigative strategies should therefore address all aspects of the problems, which are: 1) aesthetics, 2) possible contaminant movements between the contaminated sediments and the aquatic environment, 3) contaminated sediment loadings from Windermere Basin to Hamilton Harbour, and 4) the speed of sedimentation of Windermere Basin.

In 1979, Environment Canada (Ontario Region), prepared a report titled "An Investigation of the Technical Options Available to Curtail the Movement of Pollution from the Windermere Basin into Hamilton Harbour". In this report three options were identified and their advantages and problems discussed. Their report dealt with options to reduce sediment-water interactions, and are summarized below:

a) Dredging Windermere Basin: Dredging the contaminated sediments and debris from the Basin would remove the contaminated material from the aquatic environment, allow the Basin to function more efficiently as a sediment trap, and improve its appearance. Hydraulic dredging is expensive, however, with costs ranging from $2.50 to $3.00/cu. m. (1979 dollars) plus cost of equipment mobilization (approximately $100,000). There is, however no suitable disposal site nearby for the large volumes of grossly contaminated sediment. Depending on future loading rates, dredging may have to be repeated in the future as newer deposits fill in the Basin.

b) Dyking Windermere Basin: A dyke could be constructed across the narrow mouth of the Basin, raising the water level and causing ponding behind it. This would increase the retention in the Basin and the quality of the water discharged

over the dyke would improve because of increased settling. This would be a temporary solution, raising the water level in the Basin could interfere with land use in the area and possibly accentuate flooding problems. It might also have a detrimental effect on the upstream existing Redhill Creek Marsh.

c) Creation of a Marsh in Windermere Basin: If a marsh was artificially created in Windermere Basin it could aid in the vegetative uptake of heavy metals, organics, and/or nutrients currently passing through the Basin. The new marsh, as well as being more attractive than the current Basin, would partially compensate for large scale destruction of similar habitat that has occurred in Hamilton Harbour in the past. This option would require careful study as 1) the Basin sediments may not be conducive to aquatic plant growth, 2) a structure might be necessary to control water levels, and 3) problems might arise through attracting wild life to an area that is highly contaminated (bio-accumulation of toxics in the food web).

Discussion of Options

Dredging may appear to be the preferred solution to mitigate the aesthetic problems with the build-up of sediments in Windermere Basin. In addition to improving the aesthetics of the Basin, dredging would remove the contaminated material. Removal of all of the organic rich sediments would increase the trap efficiency of the Basin to over 50%. The ability of the waterbody to provide biological and chemical degradation (assimilative capacity) would increase as well. Removing just the most contaminated sediments in the upper 70 cm (which would result in a volume reduction of 280,000 m^3) would reduce potential, although not proven, source of contaminants, but would not greatly improve either the trap efficiency or assimilative capacity of the basin. Dredging, however, would have to be accompanied by a reduction in sediment loading to the Basin to ensure that it does not fill quickly. Given 1980 loading rates, refilling to the present state would probably take about 50 years if the Basin is completely dredged (1 million cubic metres).

There are, however, some serious problems with dredging the Basin. Besides the obvious technical problems associated with dredging the Basin, a problem also exists with disposing of the sediments in an environmentally acceptable way. In fact, the cost of disposal of the sediments would likely be greater than the actual dredging costs. Dredging would only be considered to alleviate the aesthetic problem. Great care would have to be taken to minimize disturbance and resuspension of sediments during dredging.

The option of dyking the basin (option b) while improving aesthetics and reducing loadings to the Harbour, would not isolate the contaminated material from the aquatic environment and can only be considered a temporary solution as build-up of sediment would be increased because of increased trap efficiency. There may also be some hydraulic problems created at the STP if water levels raised. Establishing the marsh, (option c) would enhance the aesthetics of the Basin. It could also reduce nutrient and contaminant flow through the Basin during the plant growing season. Typha sp. (cattail) colonies presently occur as a discontinuous narrow band along the perimeter of the basin. This indicates the potential for further colonization throughout Windermere Basin either as a natural expansion or from artificial plantings.

Marshes do not provide much treatment in the winter months and in fact, could allow re-introduction of contaminants either through resolubilization or resuspension, especially during high flow periods in the spring time.

A reduction of loadings to the Basin is desirable with any of the options presented.

5. SUMMARY

1. Stormwater loadings to the basin are significant and greatly exceed the sewage treatment plant loadings for suspended solids on all days that rainfall events result in combined sewer by-passing.

2. During dry weather the Hamilton Sewage Treatment Plant is a major source of the measured contaminant loadings to the Basin (1980 data).

3. On average, the Hamilton STP loading is more significant than urban non-point loadings for nutrients and heavy metals but not suspended solids.

4. A reduction in suspended solids would be necessary to reduce the rate of filling in the Basin.

5. Trap efficiency of the Basin is probably less than 20%.

6. Trap efficiency could be potentially increased to more than 50% if 1 million cubic metres of sediment were removed.

7. Sediments in Windermere Basin are heavily contaminated and exceed the guidelines for open water disposal with respect to heavy metals, nutrients and PCB's. Maximum values are found at the sediment surface in the vicinity of the sewage treatment plant outfall.

8. The Basin contains approximately 1 million cubic metres of black organic sediment.

9. Heavily contaminated sediments appear to extend to at least the 70 cm depth with a corresponding volume of at least 280,000 cubic metres.

10. MOE investigations did not conclusively indicate whether the contaminated sediments resulted in deterioration in water quality across the Basin. It appears that water quality does not change appreciably across the Basin. Further studies would be necessary to more accurately define the sediment - water chemistry dynamics.

11. Dredging the Basin would eliminate the aesthetic problem associated with the sediment build-up. However, water quality may not be improved and during dredging, would in all likelihood deteriorate as a result of disturbance of the sediment.

6. CONCLUSIONS

1. Loadings to Windermere Basin should be reduced to prevent further build-up of sediments.

   a. Suspended solids loadings from the Hamilton STP should be maintained at as low a level as practicably possible.

   b. Combined sewer overflow loadings should be minimized.

   c. Stream erosion control measures should be undertaken in the Redhill Creek Basin.

   d. Runoff from future urban development in the Redhill Creek drainage area should be controlled.

2. Preliminary evaluation indicates that the contaminated sediments in Windermere Basin may not be adversely affecting water quality across the Basin. Further studies would be required to define more accurately sediment-water chemistry dynamics to determine if water quality is being impacted.

3. The MOE cannot, at this time, recommend dredging in Windermere Basin for the following reasons:

   a) Based on preliminary evaluations, no serious impact has been measured on water quality as the water passes over the contaminated sediments.

   b) The action of dredging may, in fact, temporarily deteriorate water quality by directly introducing contaminants into the water column.

   c) The trap efficiency would not be increased sufficiently to warrant the cost of dredging.

REFERENCES

Colston, N.V., 1975 Characterization of Urban Runoff, Non-point Sources of Water Pollution, Virginia Polytechnic Institute and State University, Virginia

Chen, K.Y. 1973, Trace Metals in Wastewater Effluents, Journal. Water Pollution Control Federation, 46, 223

Chow, V.T. 1964, Handbook of Applied Hydrology, MacGraw-Hill, Inc. U.S.A.

Gould, M.S., and E.J. Genetelli, 1975, Heavy Metal Distribution in Anaerobically Digested Sludge Process., 30th Industrial Waste Conference.

Huang, C.P., H. A. Elliott and R. M. Ashmeed, 1977, Interfacial Reactions and the Fate of Heavy Metals in Soil-water Systems.

Fitchko J. and Hutchinson T.C., 1975, A Comparative Study of Heavy Metal Contractions in the River Mouth Sediments around the Great Lakes, pp 46 - 78, Vol. 1 Issue 1, Journal of Great Lakes Research.

Marsalek J., 1978; Pollution due to Urban Runoff: Unit Loads and Abatement Measures, International Joint Commission Report.

Ontario Ministry of the Environment, Nov. 1978, Goals, Policies, Objectives and Implementation Procedures of the Ministry of the Environment.

Ontario Ministry of the Environment, 1981, Outline of Analytical Methods, Laboratory Service Branch, Toronto.

Ontario Ministry of the Environment, 1976, Polychlorinated Biphenyls in the Ontario Environment, Report of the Ministry of the Environment PCB Committee

Ontario Ministry of the Environment, 1981, Evaluation of Impacts of Storm Water Runoff and Combined Sewer Overflows on Receiving Waters, 135 St. Clair Avenue West, Toronto, Ontario.

Ontario Ministry of the Environment, 1978, Hamilton Harbour Study 1976, Water Resources Branch, 135 St. Clair Avenue West, Toronto, Ontario.

Ontario Ministry of the Environment, 1978, The Effects of the Upper Ottawa Street Landfill on Redhill Creek, Water Resources Assessment, Hamilton.

Robinson, M.A., and W. James, Continuous SWMM Modelling of Summer Stormwater Runoff Quality in Hamilton, CHI Publications, January 1982.

Wilber W.G., and J. V. Hunter, 1975. Heavy Metal in Urban Runoff. Virginia Polytechnic Institute and State University, Virginia.

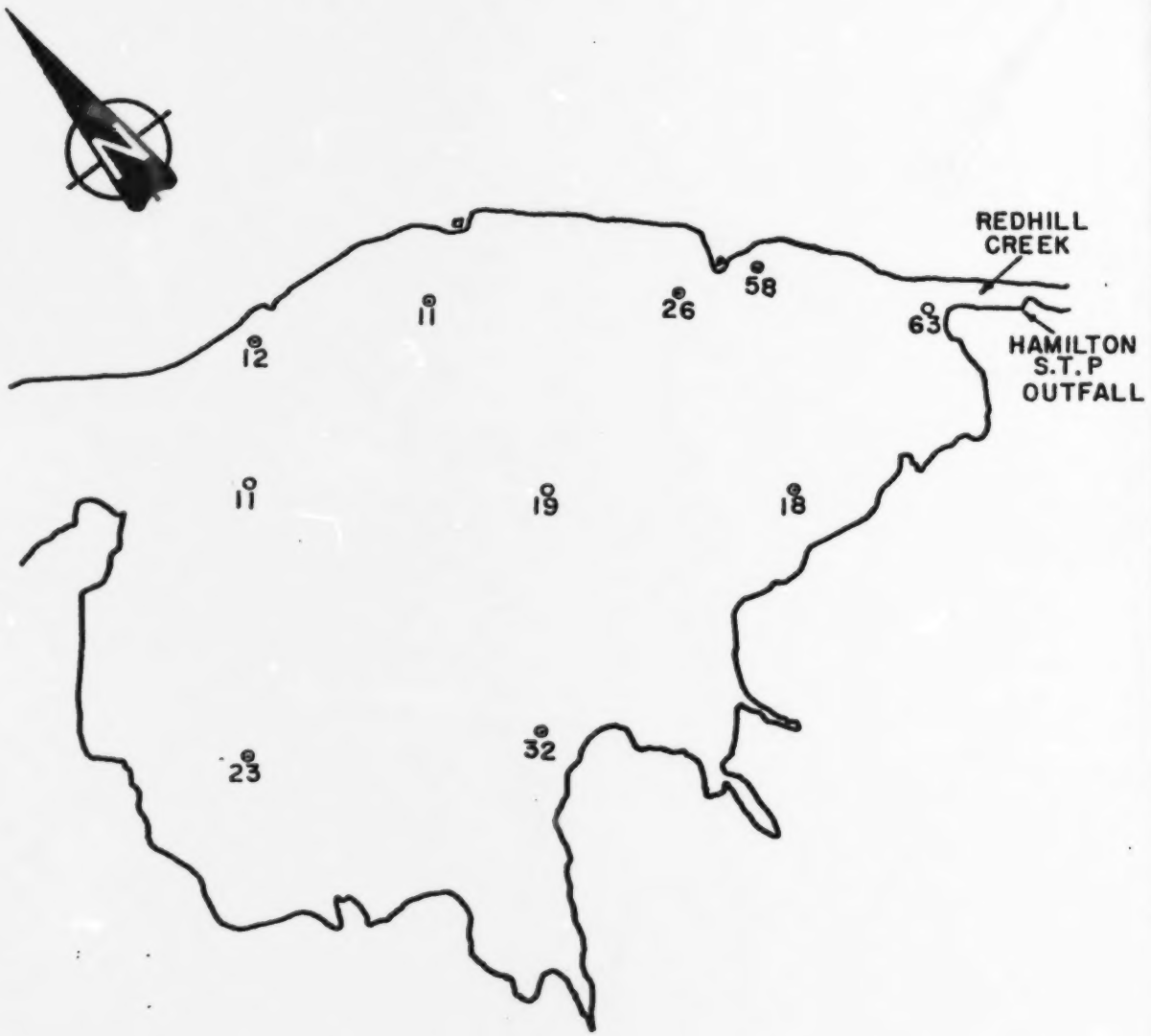
U.S. Army Coastal Engineers Research Center, 1977, Shore Protection Manual , Volume 1 page 4 - 19, Fort Belvoir, Virginia.

APPENDIX A

Sediment Chemistry Data

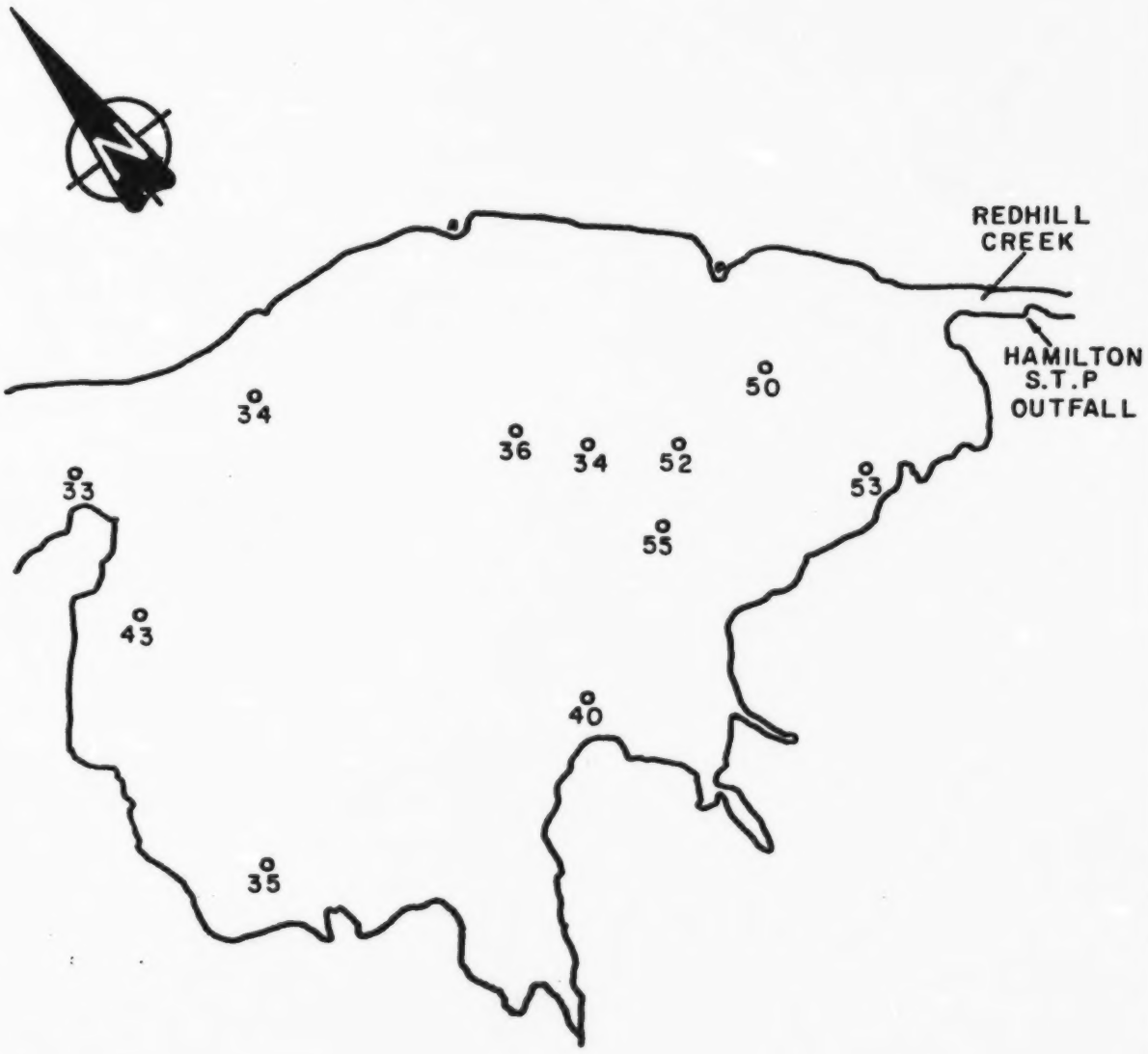
WINDERMERE BASIN SEDIMENT ANALYSIS

% SOLIDS



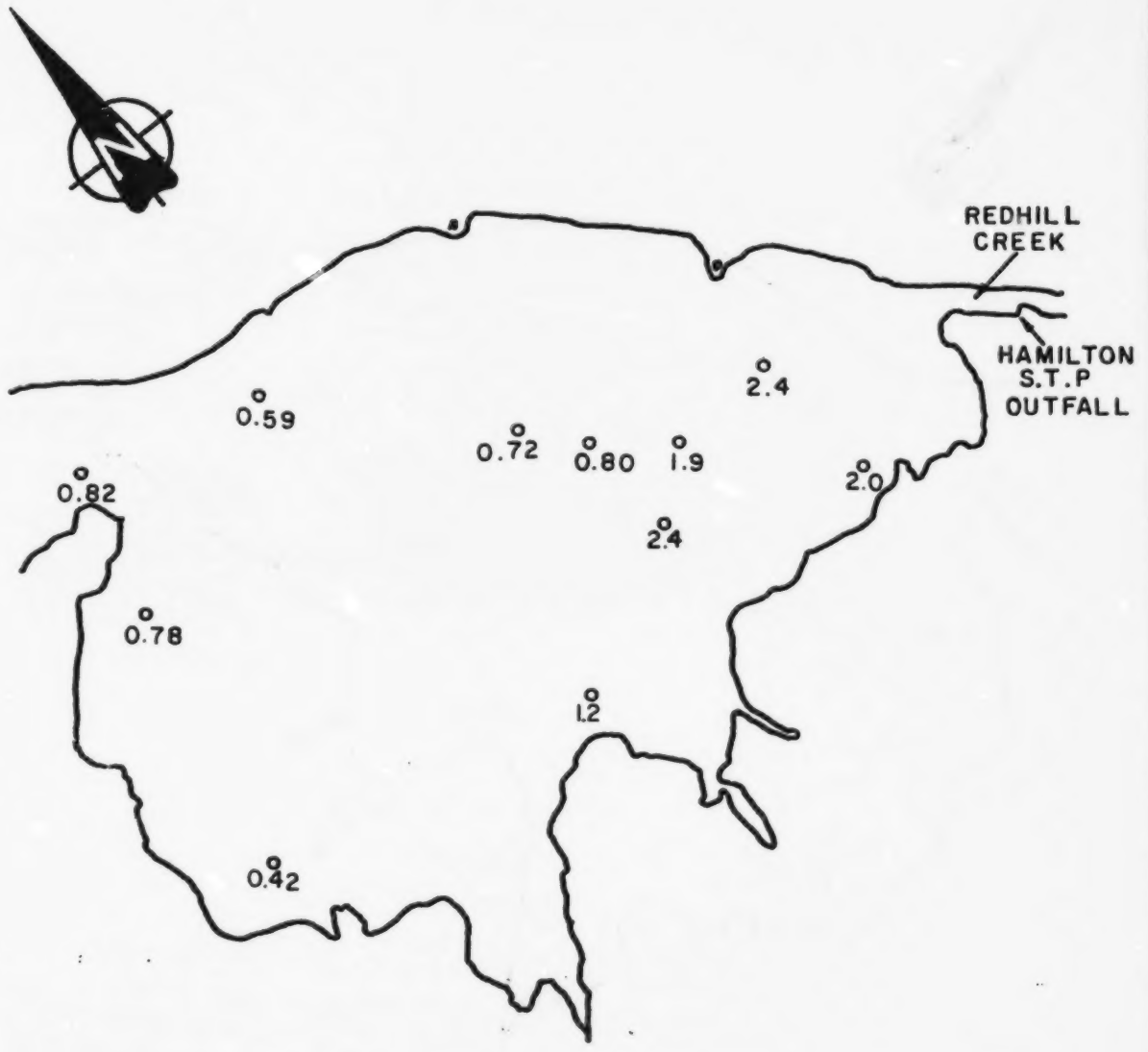
WINDERMERE BASIN SEDIMENT ANALYSIS

Total Iron



WINDERMERE BASIN SEDIMENT ANALYSIS

Total Phosphorus



o SAMPLE LOCATION

VALUES EXPRESSED AS %

0 100
METRES

URBAN DOCUMENTATION CENTRE
RESEARCH UNIT FOR URBAN STUDIES
McMASTER UNIVERSITY
HAMILTON, ONTARIO

WINDERMERE BASIN SEDIMENT ANALYSIS

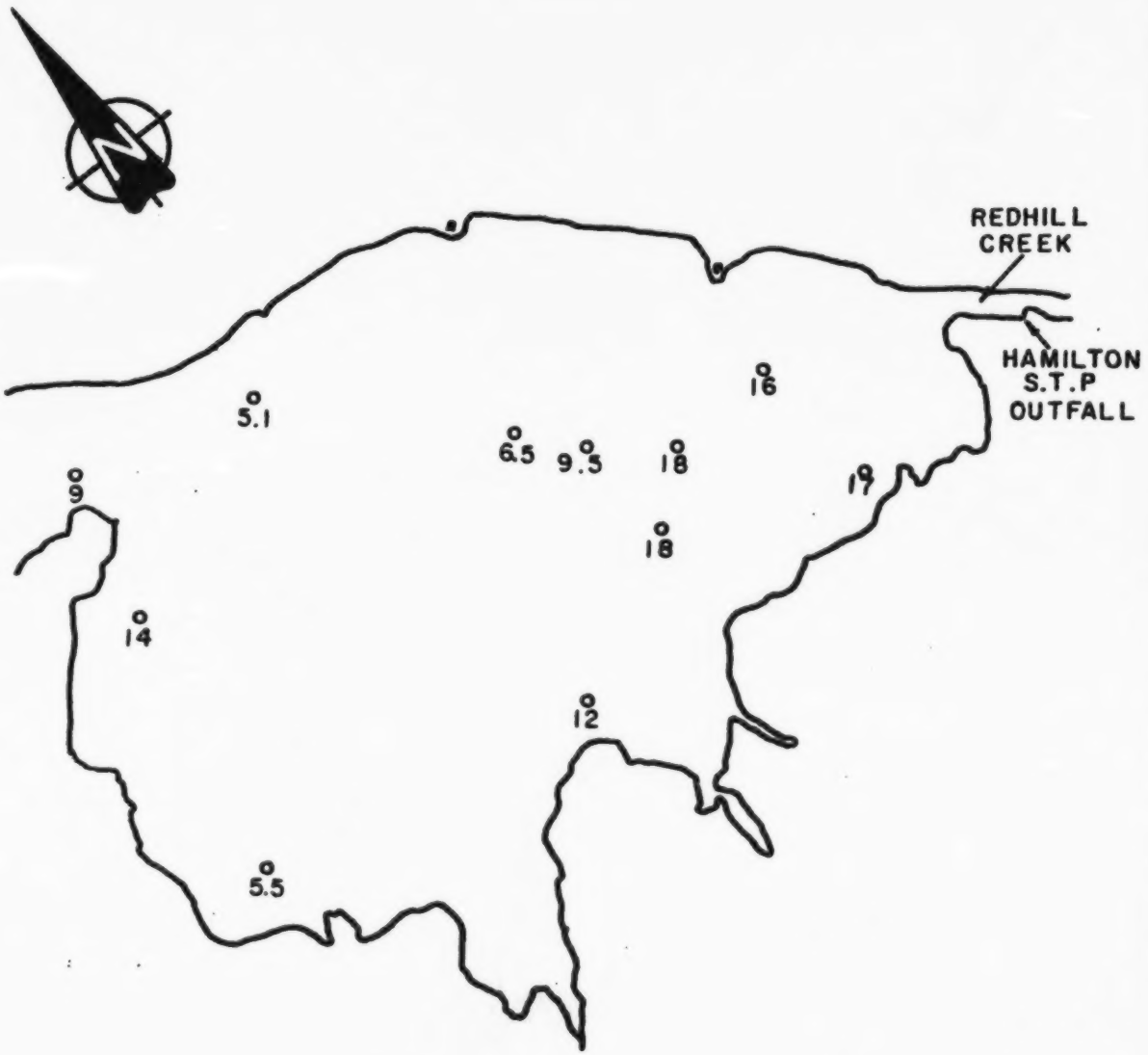
Chromium

WINDERMERE BASIN SEDIMENT ANALYSIS

Copper

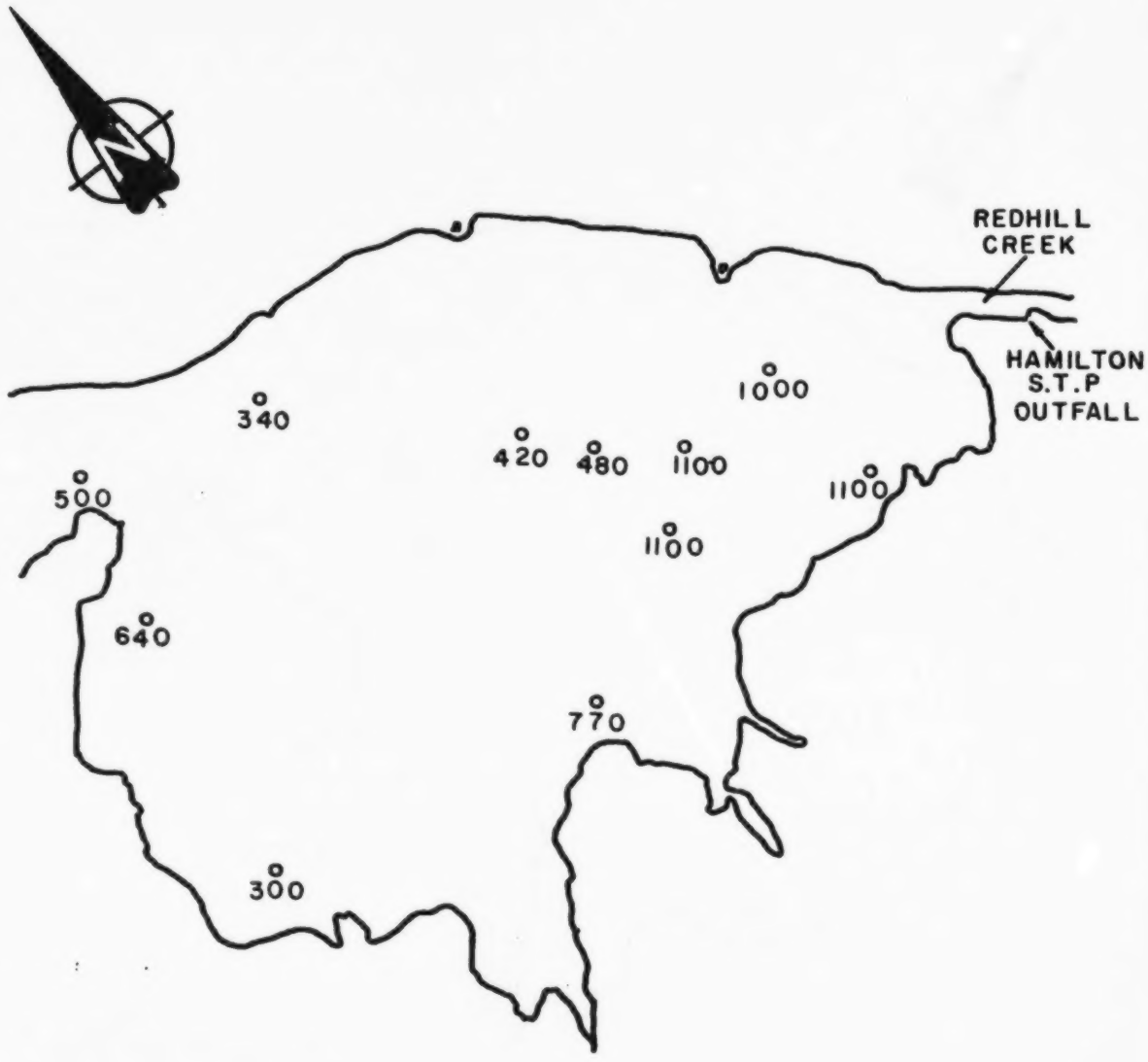
WINDERMERE BASIN SEDIMENT ANALYSIS

Cadmium



WINDERMERE BASIN SEDIMENT ANALYSIS

Lead



WINDERMERE BASIN SEDIMENT ANALYSIS

Mercury

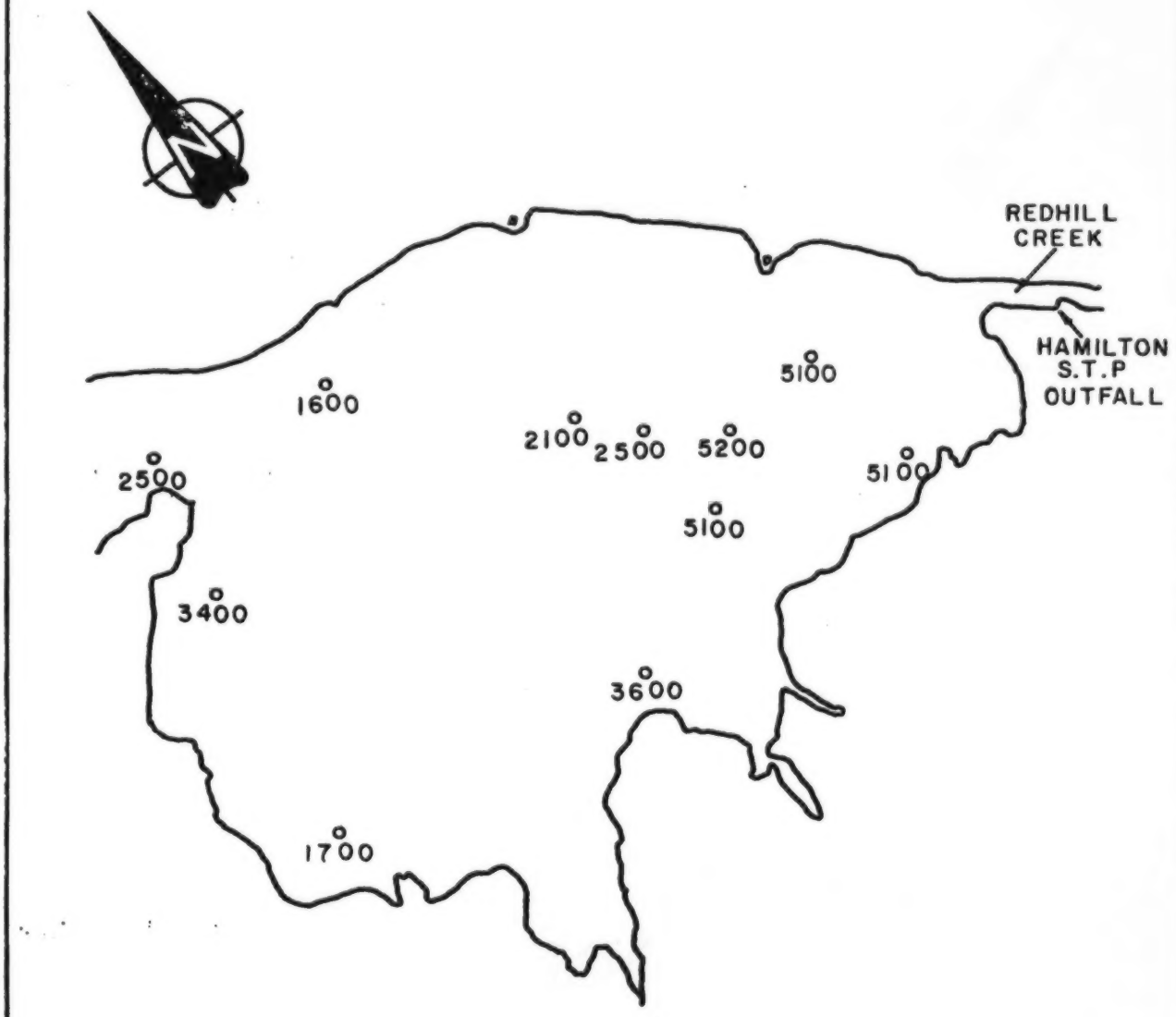
o SAMPLE LOCATION

VALUES EXPRESSED AS mg/kg

0 100
METRES

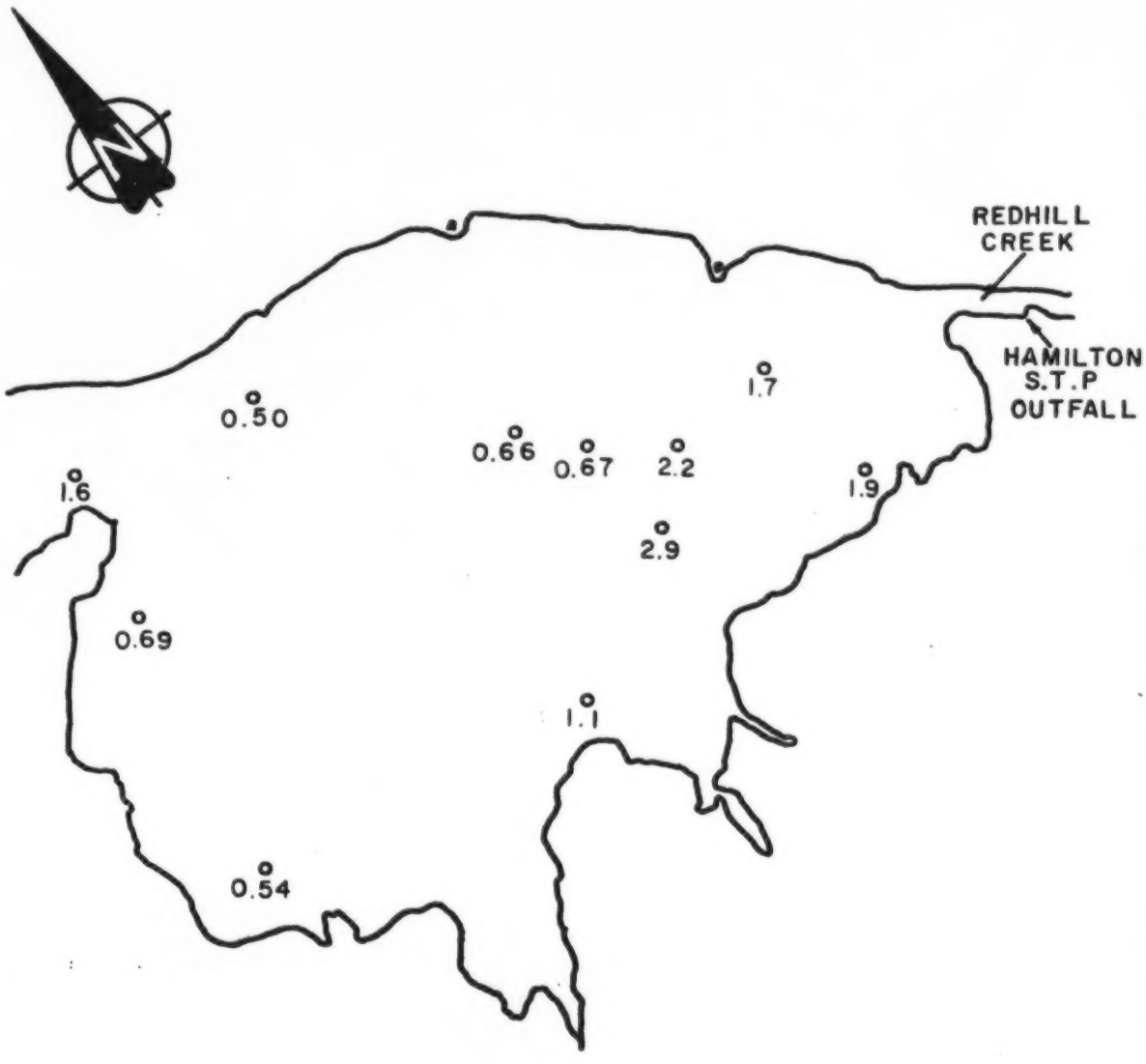
WINDERMERE BASIN SEDIMENT ANALYSIS

Zinc



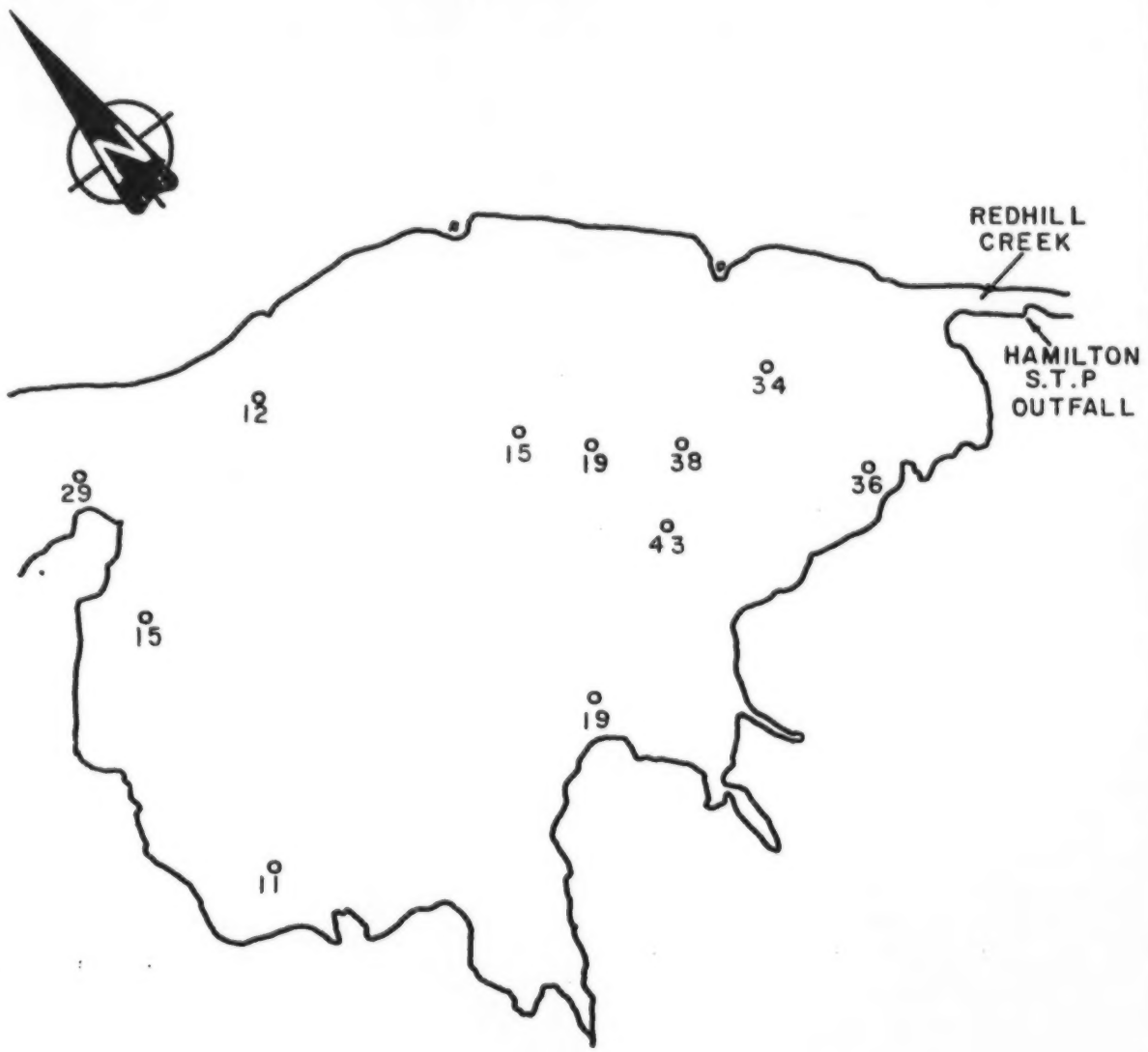
WINDERMERE BASIN SEDIMENT ANALYSIS

Total Kjeldahl Nitrogen



WINDERMERE BASIN SEDIMENT ANALYSIS

Loss on Ignition



APPENDIX B

1915 Bathymetric Map of Windermere Basin

CANADA
LAKE ONTARIO
HAMILTON HARBOUR
Surveyed by Mr G.A.Bachand, Mr J.U.Beauchemin and assistants 1915
Published under the orders of
The Honourable The Minister of Mines and Resources of Canada.
This chart is on the Polyconic Projection
Burton A Lat. 43°14'32" N., Long. 79°50'57" W.
(Geodetic Survey of Canada)
All bearings are true, thus 295°15' and are given from seaward
SOUNDINGS IN FEET
reduced to an adopted Low Water datum of 243.0 ft above Mean Sea Level or 96.7 ft below a bench mark MDCCCLIII at Hamilton.
Natural Scale, 1:5000
CAUTION: UNVERIFIED INFORMATION.
NOT TO BE USED FOR NAVIGATION.
NO REPRODUCTION WITHOUT AUTHORIZATION.
Burlington Canal
Dredged
Lights in line 56°
Spoil Area
Canadian Industries Ltd Chimney
Hydro Power Commission of Ontario
Chimney
National Steel Car Co.
Water Works Chimney

POOR

QUALITY

ORIGINAL